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RESEARCH ARTICLE

ARE VESTIBULAR FUNCTION OR VISUOSPATIAL PERCEPTION AFFECTED IN INDIVIDUALS WITH IDIOPATHIC SCOLIOSIS?

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ABSTRACT

Purpose: It was aimed to investigate the relationship between characteristics of the curve and balance, vestibular dysfunction, visuospatial perception, navigation performance, and quality of life in idiopathic scoliosis.
Material and Methods: Thirty-three participants aged 10-25 were included. The Cobb angle of the participants was recorded. The degree of rotation of the curve with the mobile application called ScolioDetector; balance parameters with the duration of unipedal stance test (eyes open-closed, right-left foot, hard-soft ground); vestibular dysfunction with the Utenberger test; visual-spatial perception with the Corsi Block Tapping test; navigation performance with the triangle completion task; and quality of life was assessed with the Scoliosis Research Society-22. In the comparison made according to type and direction of scoliosis curve, analysis was performed with the independent sample t-test or Mann-Whitney U test; Pearson correlation or Spearman correlation test was used in the relationship between Cobb and rotation angle and other parameters.
Results: In the comparison made according to the curve type, only the right eyes closed unipedal stance test duration (p=0.022) and Unterberger test rotation angle were found to be significantly different (p=0.045). According to the direction of the curve, except for the right foot unipedal stance test (eyes open) on soft ground (p=0.009) and Unterberger test displacement distance (p<0.05) and the degree of rotation with eyes open (p=0.007), no significant difference was found (p>0.05). A significant correlation was shown only between the rotation angle and the right foot eyes closed single leg stance test on soft ground. No significant correlation was found between Unterberger and Visual-Spatial Memory tests.
Conclusion: The characteristics of the curve (C or S; right or left scoliosis) affect balance and vestibular dysfunction. The rotation angle is only related to balance; it was observed that the curve features were not associated with visuospatial perception and navigation performance.

Keywords: Balance, idiopathic scoliosis, pain, vestibular dysfunction, visuospatial perception

INTRODUCTION

Idiopathic scoliosis is the most prevalent form of scoliosis, accounting for approximately 80% of structural scoliosis cases, with its underlying cause remaining largely unknown (1, 2). Anatomical abnormalities in the vestibular system, medulla oblongata, pons, and midbrain have been reported in individuals with idiopathic scoliosis (3). In MRI studies conducted between healthy individuals and individuals with idiopathic scoliosis, have revealed morphological differences in the vestibular system, including regional brain volume, corpus callosum, white matter, internal capsule, and especially semicircular canal alignment (3-5). Visual, vestibular, proprioceptive, and postural control abnormalities involving the cerebral hemispheres, brainstem, and corpus callosum have been demonstrated in idiopathic scoliosis patients (4-6). In idiopathic scoliosis, there is a disorder in the postural reflex mechanism originating from the proprioceptive organs, the vestibule of the inner ear, and the visual system during the vertebral growth period. It is also known that balance problems occurring in the balance function center in the brainstem are associated with the displacement of the vertebrae. Therefore, it is thought that brainstem dysfunction may cause idiopathic scoliosis (7). Since the vestibulospinal pathway affects the hypothalamus and cerebellum, the vestibular system has been suggested to be a possible cause of the morphological, hormonal, and neurosensory abnormalities observed in individuals with idiopathic scoliosis (8). In the etiology and definition of idiopathic scoliosis and the three-dimensional deformity of the spine, many factors such as postural asymmetry, dysfunction in the proprioceptive, vestibular, and vestibulospinal systems, and postural stability defects are noted (9). An asymmetry in vestibular function can create unbalanced stimulation of the spinal musculature and thus contribute to the development of scoliosis. One study showed that individuals with idiopathic scoliosis exhibited greater vestibular asymmetry than healthy participants (10). Research on adolescent idiopathic scoliosis has reported significant differences in balance and vestibular function compared to control groups (11,12). Apart from the typical symptoms associated with vestibular dysfunction, various cognitive processes, such as visuospatial perception ability, memory, attention, and executive function, provide insight into this system. Visuospatial perception is a term used to describe how the mind understands and organizes two- and three-dimensional space. It involves a variety of skills, including spatial memory, mental imagery, rotation, distance and depth perception, navigation, and visuospatial structure (13). Spatial memory, orientation, and mental rotation have been examined about vestibular dysfunction (13). A person's perception is the result of vestibular, visual, and somatosensory sensory integration. Studies have shown that animals with vestibular lesions have impaired visuospatial perception abilities (14). It has been proposed that alterations or absence of vestibular input may result in disruptions to an individual's mental representation of three-dimensional space. Furthermore, patients with vestibular deficits have demonstrated impaired spatial navigation abilities, particularly in environments devoid of visual cues (15).

It is thought that vestibular dysfunction may be effective in the etiology of patients with idiopathic scoliosis. Additionally, vestibular dysfunction has been associated with visuospatial perception performance. In the literature, to our knowledge, there is no study evaluating visuospatial perception performance in patients with scoliosis. Based on the information in the literature, in this study was aimed at investigating whether there is any impairment in vestibular function and visuospatial perception performance in individuals with idiopathic scoliosis and revealing the dependent/independent relationship between the two parameters.

MATERIAL AND METHODS

Study Design

This study was designed as a cross-sectional, single-center study. Study data was collected between August 2021 and June 2022. The research was previously reviewed and approved by the Inonu University Clinical Research Ethics Committee (Date: 30.06.2021, Decision No: 2021/144). This study was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from the parents of the participants under 18, and the participants over 18 read and signed the informed consent.

Participants

Participants were selected through a non-probability random sampling method from patients with idiopathic scoliosis who presented to the orthopedics outpatient clinic at Turgut Ozal Medical Center. Although it was initially planned to include a healthy control group in the study, the ongoing pandemic conditions prevented the recruitment of a sufficient number of participants, and thus the control group could not be included. Scoliosis-specific analysis was performed. Individuals who had no additional joint deformities, no cognitive impairment, and were diagnosed with idiopathic scoliosis by an orthopedist between the ages of 10-25 were included in the study. Individuals with other types of scoliosis, those with severe hearing and visual impairment other than idiopathic scoliosis, those with any neurological, orthopedic, metabolic, or rheumatological disorders, those with benign paroxysmal positional vertigo,

Table 1. Demographic characteristics of individuals with idiopathic scoliosis

	Total (n=33)
Age, year, mean± SD	15.27±2.28
Gender, F/M	25/8
BMI, mean± SD	18.95±3.31
Dominant hand, R/L	32/1

F: Female, M: Male, BMI: Body mass index, R: Right, L: Left, SD: Standard deviation

Meniere's primary pathologies of the ear, and those with a history of serious infection (ear, internal organs), and those who had undergone a scoliosis-specific exercise program within the last year were excluded from the study. Participants who did not comply with the evaluations, who left the evaluations unfinished, and who did not sign the informed consent form were excluded from the study.

Sample Size

In the power analysis performed before the study, it was calculated that at least 14 participants should be included, assuming that idiopathic scoliosis is seen in 1% of the general population (16). The sample size calculation was performed using OpenEpi version 3 (http://www.openepi.com).

Measurements

Demographic variables such as age, gender, weight, height, as well as dominant hand information of all participants were recorded.

Balance performance was evaluated with a unipedal stance test. Individuals' right and left foot single leg stance times were recorded in seconds with a stopwatch on soft/hard ground and with eyes open/closed (17).

Vestibular dysfunction was evaluated with the Unterberger test (Fukuda stepping test). In this test, participants counted in place with 45 degrees of hip flexion for 50 steps, and after 50 steps, the rotation angle between the initial position and the final position of the right foot was measured with a goniometer, and the displacement distance was measured with the help of a tape measure The test was applied in two different positions, with eyes open and closed (18,19).

Spatial memory for visuospatial perception was evaluated with the mobile application called Visuospatial Memory Test, which was inspired by the Corsi Block Tapping test. In the application, pink squares appear on the screen, and the squares that individuals need to mark are indicated. Participants were asked to make the resulting markings in the same way. As soon as he confused the order of the markings, the test ended, and the highest span scores were recorded (20). Navigation performance was evaluated with the triangle completion task. In the navigation performance, two triangles (one equilateral triangle and one right triangle, at angles of 30°, 60°, and 90°, respectively) with lengths between 150 and 300 cm were marked on the ground. Participants were asked to place their feet on the pre-marked area at the common starting point of the two triangles and to complete the two triangles with their eyes open, first the larger triangle and then the smaller triangle. The test with eyes open was a trial phase. During the main assessment, participants were asked to complete triangle tasks with their eyes closed. The distance between the initial and final positions of the reference right big toe was recorded in centimeters (21).

The degree of rotation was evaluated with the help of a mobile application called ScolioDetector. They were asked to bend forward with their hands. During this process, care was taken to ensure that their bodies were parallel. The highest point of the hump on the spine was determined, and the smartphone was placed perpendicular to the spine. The degree of rotation was recorded (22).

Quality of life was evaluated with the Scoliosis Research Society-22 questionnaire. The survey consists of a total of 36 items and 8 sub-parameters: body pain, physical function, emotional well-being, limitation due to emotional problems, limitation due to physical problems, social function, energy/fatigue, and general health perception. Low scores on the questionnaire were associated with poor quality of life (23,24).

The Cobb angle, type and direction of the curve, and localization of scoliosis were evaluated through routine radiography taken by the orthopedist. In Cobb angle measurement, tangent lines were drawn from the upper-end plate of the upper vertebra participating in the curvature and from the lower-end plate of the lowest vertebra participating in the curvature. The angle formed where these two lines intersected was recorded as the Cobb angle (25).

Statistical Analysis

Normality evaluation of the participants' data was made with the Shapiro-Wilk Test. Among descriptive statistics, mean and standard deviation were used. In

Table 2. Comparison of balance, vestibular dysfunction, visuospatial perception, navigation performance, and quality of life according to the type of curve

	C Scoliosis (n=17)	S Scoliosis (n=16)	*p*
Cobb Angle (°)	22 (10/53)	29 (10/51)	0.211[a]
Rotation Angle (°)	2 (1/33)	7 (2/20)	0.102[b]
Unipedal Stance Test, s			
Rigid Surface, EO, R	60 (16.59/60)	60 (4.73/60)	0.759[b]
Soft Surface, EO, R	56.61 (5.14/60)	22.32 (5.62/60)	0.115[b]
Rigid Surface, EO, L	60 (0.19/60)	60 (24.07/60)	0.450[b]
Soft Surface, EO, L	42.12 (4.46/60)	19.13 (4.95/60)	0.410[b]
Rigid Surface, EC, R	20.46 (3/60)	7.61 (2.22/46.20)	**0.022[b]**
Soft Surface, EC, R	6.11 (1.64/22.35)	3.63 (1.65/60)	0.171[b]
Rigid Surface, EC, L	11.42 (2.37/48.70)	9.78 (4.29/47)	0.829[b]
Soft Surface, EC, L	6.76 (1.85/60)	4.86 (1.77/19.55)	0.150[b]
Unterberger test			
Distance of Displacement, EO, m	14.5 (1/87)	135 (1/57.50)	0.564[b]
Distance of Displacement, EC, m	45 (6/115)	48.75 (13.50/99)	0.745[a]
Angle of rotation, EO, (°)	13 (2/72)	24 (8/73)	**0.045[b]**
Angle of rotation, EC, (°)	20 (3/83)	16.5 (3/57)	0.601[b]
Visuospatial Memory Test			
Highest Span	5 (4/9)	6 (3/6)	0.734[b]
Reaction time	1020.70 (460.40/1438.50)	928.45 (489/1913.50)	0.729[a]
Navigation Performance			
30-60-90 Triangle, m	45 (6/157)	54.50 (7/147)	0.871[b]
60-60-60 Triangle, m	26 (1,5/101)	30.50 (2/170)	0.957[b]
SRS-22			
Function	4.6 (2.60/5)	4.60 (2.20/5)	0.645[b]
Pain	4.2 (1.80/5)	3.90 (2.80/5)	0.704[b]
Body image	3.20 (1.60/5)	3.20 (2.20/4.60)	0.640[a]
Mental health	3.2 (1.80/5)	3.70 (1.60/4.60)	0.772[b]

EO: Eyes open, EC: Eyes close, R: Right, L: Left, s: second, m: Meter, SRS-22: Scoliosis Research Society- 22. [a]Independent Sample T test, [b] Mann Whitney U test

the comparison made according to the type of scoliosis curve and the direction of the deficit, analysis was performed with the independent sample t-test or Mann-Whitney U test, depending on the normality of the data. In the correlation analysis, the Pearson correlation test, or Spearman correlation test, was used according to the normal distribution in the relationship between Cobb and rotation angle and other parameters. Correlation coefficient (r); It was interpreted as 0.00–0.20 poor, 0.21–0.40 fair, 0.41–0.60 good, 0.61–0.80 very good, 0.81–1.0 excellent p<0.05 was considered statistically significant. The data were analyzed with Statistical Package for the Social Sciences (SPSS) version 25.0.

RESULTS

During the study period, 38 patients were evaluated for eligibility. A total of 2 patients (short limbs, genetic disorder) were not included because they did not meet the eligibility criteria. 36 patients participated in the evaluation. Three participants could not be included in the analyses due to missing data, and the analysis had been carried out with a total of 33 participants. Demographic data and dominant hand information of the individuals are given in Table 1.

In the analysis performed according to the type of curve, there was no difference in Cobb and rotation angles between the groups (p>0.05). In the comparison of the unipedal stance test between the groups, it was found that the right foot eyes closed test performance in the group with only the S scoliosis curve was significantly lower than in the C scoliosis group (p = 0.022). There was no difference in other unipedal stance test performances between the groups (p>0.05). In the Unterberger test, the eyes-open rotation angle in the S scoliosis group was significantly higher than the C scoliosis group (p = 0.045). There was no significant difference between

Table 3. Comparison of balance, vestibular dysfunction, visiospatial perception, navigation performance and quality of life according to the direction of the primary curve

	Right (n=22)	**Left (n=11)**	***p***
Cobb Angle (°)	24 (10/51)	31 (10/53)	0.467[b]
Rotation Angle (°)	4.50 (1/33)	8 (2/20)	0.286[b]
Unipedal Stance Test, s			
Rigid Surface, EO, R	60 (4.73/60)	60 (12.20/60)	0.319[b]
Soft Surface, EO, R	24.99 (5.14/60)	60 (7.96/60)	**0.009[b]**
Rigid Surface, EO, L	60 (0.19/60)	60 (28.84/60)	0.279[b]
Soft Surface, EO, L	26.89 (4.46/60)	33.86 (12.20/60)	0.691[b]
Rigid Surface, EC, R	9.79 (3/34.65)	14.10 (2.22/60)	0.422[b]
Soft Surface, EC, R	4.14 (1.65/22.35)	5.09 (1.64/60)	0.661[b]
Rigid Surface, EC, L	11.72 (2.37/47)	10.20 (5.23/48.70)	0.789[b]
Soft Surface, EC, L	6.73 (1.77/60)	4.27 (1.85/19.55)	0.169[b]
Unterberger test			
Distance of Displacement, EO, m	12.75 (1/52.50)	24 (1/87)	**0.049[b]**
Distance of Displacement, EC, m	40 (6/99)	61.50 (33/115)	**0.008[a]**
Angle of rotation, EO, (°)	23.35 (5/73)	10 (2/40)	**0.007[b]**
Angle of rotation, EC, (°)	25.50 (3/83)	14 (5/48)	0.089[b]
Visuospatial Memory Test			
Highest Span	5 (4/9)	6 (3/7)	0.389[b]
Reaction time	1037 (489/1438.50)	848.90 (460.40/1913.50)	0.693[a]
Navigation Performance			
30-60-90 Triangle, m	49.50 (8/157)	50 (6/147)	0.660[b]
60-60-60 Triangle, m	30.50 (1.50/170)	24 (2/92)	0.593[b]
SRS-22			
Function	4.50 (2.20/5)	4.60 (3.20/5)	0.845[b]
Pain	4 (1.80/5)	4.20 (3/4.80)	0.618[b]
Body image	3.20 (1.60/5)	3 (2.20/4.40)	0.952[a]
Mental health	3.40 (1.60/5)	3.80 (2.20/4.20)	0.388[b]

EO: Eyes open, EC: Eyes close, R: Right, L: Left, s: second, m: Meter, SRS-22: Scoliosis Research Society- 22. [a]Independent Sample T test, [b] Mann Whitney U test

the groups in Visuospatial Memory Test scores, navigation performance, and SRS-22 survey sub-scores (p>0.05) (Table 2).

Cobb and rotation angles were similar in the groups according to the direction of the curve opening (p>0.05). Unipedal stance test performance had no difference between the groups in all subparameters (p>0.05), except for the duration of the right extremity standing on one foot with eyes open on soft ground (p=0.009). The Unterberger test showed that the amount of displacement with eyes open and closed was significantly lower in individuals with a right-facing curve than in the group with a left-facing aperture curve (p=0.049, p=0.008, respectively). While there was a significant difference between the groups in the eyes-open rotation angle (p=0.007), there was no difference between the groups in the eyes-closed rotation angle (p>0.05). There was no significant difference between the groups in Visuospatial Memory Test scores, navigation performance and SRS-22 survey sub-scores (p>0.05) (Table 3).

In participants with scoliosis, a negative correlation was shown between the Cobb angle and the duration of unipedal stance test on the right and left soft ground with eyes closed, respectively at a moderate (p = -0.313) and good level (r = -0.414). There was no significant correlation between other unipedal stance test performances (p>0.05). There was a fair negative correlation between the Cobb angle and the eyes-closed rotation angle of the Unterberger test only (p=-0.300). There was no significant correlation between Cobb angle and navigation performance and SRS-22 (function, body image, mental health) (p>0.05). There

Table 4. Relationship of Cobb and rotation angle with other parameters

		Cobb Angle	Rotation Angle
Unipedal Stance Test			
Rigid Surface, EO, R	**r**	-0.078	0.061
	p	0.665[b]	0.737
Soft Surface, EO, R	**r**	-0.118	0.115
	p	0.513[b]	0.525
Rigid Surface, EO, L	**r**	0.085	0.188
	p	0.638[b]	0.294
Soft Surface, EO, L	**r**	-0.132	0.114
	p	0.464[b]	0.526
Rigid Surface, EC, R	**r**	-0.214	-0.164
	p	0.231[b]	0.361
Soft Surface, EC, R	**r**	-0.313	**-0.433***
	p	0.076[b]	**0.012**
Rigid Surface, EC, L	**r**	-0.038	-0.015
	p	0.834[b]	0.934
Soft Surface, EC, L	**r**	-0.414	-0.274
	p	0.017[b]	0.123
Unterberger test			
Distance of Displacement, EO, m	**r**	0.052	0.113
	p	0.775[b]	0.530
Distance of Displacement, EC, m	**r**	-0.202	-0.023
	p	0.259[a]	0.898
Angle of rotation, EO, (°)	**r**	0.195	0.208
	p	0.277[b]	0.245
Angle of rotation, EC, (°)	**r**	-0.300	-0.254
	p	0.090[b]	0.154
Visuospatial Memory Test			
Highest Span	**r**	-0.237	-0.087
	p	0.183[b]	0.629
Reaction time	**r**	0.130	0.123
	p	0.470[a]	0.495
Navigation Performance			
30-60-90 Triangle, m	**r**	-0.089	0.030
	p	0.622[b]	0.869
60-60-60 Triangle, m	**r**	0.040	0.008
	p	0.827[b]	0.963
SRS-22			
Function	**r**	-0.291	-0.215
	p	0.100[b]	0.230
Pain	**r**	-0.383	-0.231
	p	0.028[b]	0.195
Body image	**r**	-0.115	-0.135
	p	0.525[a]	0.452
Mental health	**r**	-0.185	-0.190
	p	0.304[b]	0.289

EO: Eyes open, EC: Eyes close, R: Right, L: Left, m: Meter, SRS-22: Scoliosis Research Society- 22. [a]Pearson correlation test, [b]Spearman correlation test

was a moderate negative correlation with the SRS-22 pain sub-parameter (p = -0.383) (Table 4).

There was no significant difference between all subparameters of the unipedal stance test (p>0.05), except for the rotation angle and the duration of standing on a single leg with eyes closed on the right soft ground (p=-0.433). There was no significant correlation between rotation angle and Unterberger test, visuospatial memory test, navigation performance and SRS-22 (p>0.05) (Table 5).

Table 5. The relationship between vestibular dysfunction and visuospatial perception disorder in individuals with scoliosis

			Visuospatial Memory Test[a]	
			Highest Span	Reaction time
Unterberger test[a]	Distance of Displacement, EO, m	r	0.041	-0.018
		p	0.823	0.920
	Distance of Displacement, EC, m	r	0.006	0.061
		p	0.975	0.735
	Angle of rotation, EO, (°)	r	-0.043	0.110
		p	0.810	0.543
	Angle of rotation, EC, (°)	r	-0.145	0.020
		p	0.421	0.912

EO: Eyes open, EC: Eyes close, m: Meter. [a]Spearman correlation test

Additionally, there was no significant correlation between Unterberger test subparameters and Visuospatial Memory Test scores (p>0.05).

DISCUSSION

In the analysis according to the type of curve; although there is a similarity in cobb and rotation angles, in the test performance in the eyes closed right standing (unipedal stance test) and eyes open rotation angle (unterberger test); it is seen that patients with S scoliosis are more affected than patients with C scoliosis. The direction of curvature is in the right group; It is observed that the duration of standing on soft ground with eyes open (unipedal stance test) with the right extremity has lower scores than the left extremity. In addition, it was observed that the amount of displacement with eyes open and closed (Unterberger test) had lower scores in the group with right-sided curvature than in patients with left-sided curvature. Negative correlation (moderate and good) was observed between the cobb angle and unipedal stance test, unterberger test rotation angle, SRS-22 pain sub-parameter with eyes closed. In addition, a negative correlation was observed between the rotation angle and the duration of standing on soft ground with the right extremity.

Three-dimensional deformity of the spine in patients with adolescent idiopathic scoliosis leads to negative changes in sensory and motor processes (26). Negative effects on sensory and motor processes cause asymmetries in muscle strength around the spine, leading to changes in the center of body mass. This leads to an increase in balance and postural oscillations (27). In studies in which patients with AIS and healthy individuals were examined; Gauchard et al. reported significant differences in both static and dynamic balance parameters (28), Simoneau et al. reported that patients with AIS were weaker in standing balance (29). Force transfers in the form of kinetic chains will cause major changes in balance while performing static and dynamic activities, along with changes in spinal stability and neutral spinal alignment (30). Our study findings are consistent with the literature. In the light of the information in the literature, we think that spinal stability and neural spine alignment might be adversely affected in patients with S scoliosis compared to patients with C scoliosis. With this situation, we hypothesize that the effects that may occur in the muscle and soft tissue structures around the spine will be greater. We hypothesize that these effects may exacerbate adverse events in the vestibular, somatosensory and visual systems, resulting in worse balance and vestibular function in patients with S scoliosis than in patients with C scoliosis.

In a study examining the relationship between foot stability and postural changes in patients with AIS, a decrease in foot stability was observed in patients with AIS. It was reported that decreased foot stability negatively affected balance (31). In a study in which the relationship between standing balance parameters and body somatotype was investigated in girls with AIS, it was reported that increased oscillations was observed in children with endormorphic structure compared to the healthy group, while children with ectomorphic structure tended to lean backwards compared to the healthy group. As a result, it was reported that postural responses and balance were related with body somatotype (32). It has been reported that pelvic abnormal growth in girls with right thoracic scoliosis negatively alters the relationship between body and trunk center of mass (33). As far as we reviewed the literature, there are studies reporting that hand preferences in patients with scoliosis are related with the strength of the direction of asymmetry and trunk asymmetry, curve pattern and convexity of scoliosis (34, 35). In young adults with AIS, it has been reported that static balance is mostly related to sagittal balance, 67% of patients with a leftward orientation of curvature place weight on the back, whereas this rate is 89% in patients with a rightward orientation of curvature. In addition, it has been reported that regardless of whether the direction of curvature is left or right, there is a tendency to place more weight on the right (36). Considering the patient profile in our study, right dominance (32 right, 1 left) and right predominance in the direction of the curve aperture (22 right, 11 left in the direction of the curve aperture) were prominent. Balance of standing on the limbs and vestibular involvement are more common on the right side. We hypothesize that patients expending more energy on the dominant side, putting more weight on the right side and loading most of the weight on the back may negatively affect the balance, and that the body somatotype, right dominance and the direction of the curve of the patients included in the study may be due to different compensation mechanisms of right dominance in order to achieve balance.

Negative correlation (moderate and good) was observed between the cobb angle and unipedal stance test, unterberger test rotation angle, SRS-22 pain sub-parameter with eyes closed. In addition, a negative correlation was observed between the rotation angle and the duration of standing on soft ground with the right extremity. When the studies in the literature are examined, it is reported that patients with AIS have increased body oscillations when the eyes are closed and have difficulties in maintaining balance (37,38). It has been reported in the literature that Cobb angle is associated with trunk morphology, asymmetric bone growth, ground reaction force and neuromuscular control (41-43). The findings of our study are consistent with the studies in the literature. In cases where vision is eliminated, increased Cobb angle in patients is associated with poor balance and vestibular function. Based on the literature, the increase in the curve in individuals with scoliosis explains the impairments in balance and vestibular systems due to impaired neuromuscular control.

The limitations of our study are that our patients with scoliosis did not show homogeneous distribution according to curve type and direction of the curve, we did not have a control group, and the physical activity levels of the patients were not evaluated when balance and vestibular functions were considered. In addition, the strengths of this research were that we made detailed analyses according to the direction of the curve. Additionally, using a mobile application to evaluate visuospatial memory performance is important for the objectivity and applicability of our results.

CONCLUSION

This study is, to our knowledge, the first to investigate the relationship between curve features, unipedal stance test performance, vestibular dysfunction, navigation performance, visuospatial memory, and quality of life in individuals with idiopathic scoliosis. As a result, it was shown that there was no difference in visuospatial memory, navigation performance, and quality of life in individuals with idiopathic scoliosis, depending on the type of curve and the direction of the opening of the curve. In particular, it was found that the direction of the curve caused a difference in terms of vestibular dysfunction. There were no significant correlations between Cobb and rotation angle and unipedal stance test, vestibular dysfunction, visuospatial memory, navigation performance, and quality of life. However, no relationship was shown between vestibular dysfunction and visuospatial memory performance in individuals with scoliosis. Further studies are needed to investigate the relationship between these parameters in order to understand the etiology of scoliosis.

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